Fishery Data Series No. 06-38

Estimation of Coho Salmon Abundance and Spawning Distribution in the Unalakleet River, 2005

by

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and

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July 2006

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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July 2006

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This document should be cited as:
Joy, P. and D. J. Reed. 2006. Estimation of coho salmon abundance and spawning distribution in the Unalakleet River, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 06-38, Anchorage.

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ABSTRACT

The Unalakleet River supports the largest and arguably most important coho salmon run in Norton Sound. To monitor salmon escapement in the Unalakleet River drainage, a counting tower has been in operation for several years on the North River, a large tributary. A 3-year investigation was initiated in 2004 to describe the extent to which the North River tower counts index escapement of coho salmon into the entire Unalakleet River drainage. This report describes results from 2005, the second year of the study.

Between July 20 and September 16, 2005, 287 coho salmon were captured with beach seines in the lower portion of the Unalakleet River and fitted with esophageal radio tags. Final spawning destinations of radio-tagged coho salmon were determined using four stationary receiving stations positioned throughout the drainage and four aerial flights of the entire drainage. Coho salmon were also sampled for age, sex, and length data above the North River counting tower and in the Unalakleet River above the North River confluence. Two sample mark-recapture techniques were used to estimate total drainage abundance.

A population abundance estimate of 134,531 coho salmon (SE=28,550; 95% credibility interval of 111,800 to 223,500) was generated for the entire Unalakleet River drainage, and 19,189 were counted past the North River tower. The proportion of coho salmon entering the Unalakleet River that migrated past the North River tower was 14% in 2004 and 15% in 2005, which indicates the North River supports a moderate, but consistent fraction of the run. All aged coho salmon were determined to be either age-2.1 or -1.1. Similar proportions of both ages of fish were observed in the North and Unalakleet rivers throughout the run. Coho salmon sampled in the North River were smaller, on average, than those sampled in the Unalakleet River, and the run timing pattern of North River coho salmon was similar to the pattern for those returning to other parts of the drainage.

Coho salmon migrated into all tributaries of the drainage with the largest concentration of fish migrating to the stretch of the Unalakleet River above the Chiroskey River and below the North Fork Unalakleet River. Later running fish tended to congregate in the portion of the Unalakleet below the North Fork and above the Chiroskey River, although tributary spawners were seen throughout the run. Estimated proportions of coho salmon migrating to various portions of the drainage were 0.143 (SE=0.024) to the North River, 0.573 (SE=0.047) to the mainstem of the Unalakleet River below the North Fork, and 0.284 (SE=0.040) to the upper Unalakleet and it's tributaries including 0.017 (SE=0.009) to the Chiroskey River, 0.092 (SE=0.021) to the Old Woman River, 0.030 (SE=0.011) to the North Fork, and 0.608 (SE=0.041) through the Federal Wild and Scenic portion of the river. An estimate of abundance for coho salmon entering the wild and scenic portion of the river was 81,798 (SE=22,070).

Key words: coho salmon, counting tower, escapement, mark-recapture, North River, *Oncorhynchus kisutch*, radiotelemetry, spawning distribution, Unalakleet River.

INTRODUCTION

The Unalakleet River is a clear, run-off river that drains an area approximately 5,400 square km as it flows southwesterly through the Nulato Hills into Norton Sound (Sloan et al. 1986; Figure 1). The river supports a large run of coho salmon *Oncorhynchus kisutch* as well as runs of Chinook salmon *O. tshawytscha*, chum salmon *O. keta* and pink salmon *O. gorbuscha*. The Unalakleet River also supports resident populations of Dolly Varden *Salvelinus malma* and Arctic grayling *Thymallus arcticus*.

Unalakleet River coho salmon stocks support substantial subsistence and sport fisheries as well as the largest commercial coho salmon fishery in Norton Sound. The Norton Sound District 6 commercial fishery occurs very near the mouth of the Unalakleet River and the majority of fish caught in that fishery are believed to be Unalakleet River stocks. The 2005 District 6 commercial harvest estimate was 85,255 coho salmon with a recent 5-year average (2001-2005) of 35,667 fish. Subsistence harvests have ranged from 4,988 to 16,081 from 1994-2003, and the most recent 5-year (1999-2003) average harvest was 6,294. The recent 5-year average (2000-2004) annual sport coho salmon harvest was 2,987 fish (Table 1; DeCicco 2004).

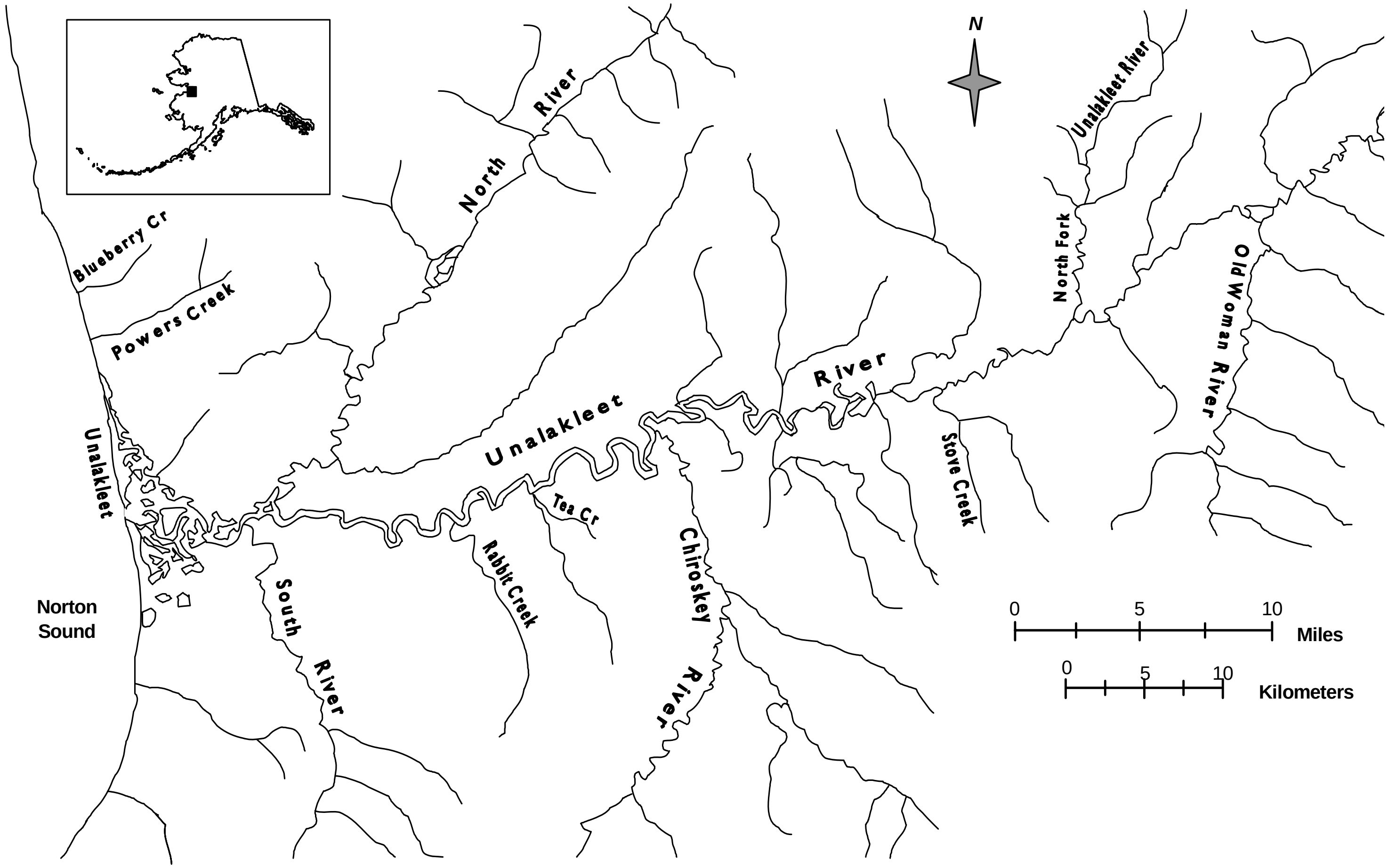

Figure 1.–Map of the Unalakleet River and its tributaries.

Table 1.–Unalakleet River coho salmon commercial, subsistence and sport harvest, sport catch and counts from the North River tower, 1980-2003.

Brood Year	North River Tower Counts	Last Day of Operation	District 6 Commercial Harvest	District 6 Subsistence Harvest	Unalakleet River Sport Catch	Unalakleet River Sport Harvest
1980			21,512	4,758		
1981			29,845	5,808		
1982			61,343	7,037		
1983			36,098	6,888		
1984			47,904	6,675		
1985			15,421	2,244		
1986			20,580			
1987			15,097			
1988			24,232			
1989			36,025	4,681		
1990			52,015		3,396	1,826
1991			52,033		2,882	2,180
1992			84,449		2,802	1,555
1993			26,290		1,572	643
1994			71,019	16,081	2,488	2,425
1995			31,280	13,110	3,086	2,033
1996	1,229	25-Jul	52,200	15,963	5,863	3,411
1997	5,768	26-Aug	26,079	9,120	4,020	2,784
1998	3,361	12-Aug	24,534	7,303	3,213	2,742
1999	4,792	31-Aug	10,264	8,140	9,593	2,691
2000	6,959	12-Aug	29,803	5,878	9,184	4,103
2001	12,383	15-Sep	15,102	6,270	5,399	2,766
2002	2,966	28-Aug	1,079	4,988	3,691	2,937
2003	5,837	13-Sep	13,027	6,192	2,832	1,604
2004	11,187	14-Sep	29,282	n/a	12,655	3,524
2005	19,189	14-Sep	85,255	n/a	n/a	n/a
<u>5 Year Average</u>						
2000-2004					6,752	2,987
2001-2005			35,667			
1999-2003				6,294		

Note: Shaded cells indicate an incomplete count of the run.

In the past 10 years there has been a noticeable increase in the number of sport fishermen participating in the Unalakleet River coho salmon fishery. This increase is of concern to the Unalakleet area residents, who use the coho salmon as a primary subsistence food. In 2003, Unalakleet residents approached Alaska Department of Fish and Game (ADF&G) and U.S. Bureau of Land Management (BLM) over their concern about the rising amount of sport angling and their uncertainty in escapement estimates for coho salmon.

Escapement of Unalakleet River coho salmon is monitored by a counting tower located on the North River, a large tributary system draining into the lower river. The tower has been operated by two different regional organizations. From 1996-2001 it was operated by Kawerak Inc., and in 2002 the Unalakleet Indian Reorganizational Act Council (IRA) took over operation of the tower with assistance from ADF&G – Commercial Fisheries Division (CFD). The counting tower is typically in operation from June 15 through September 10. In past years tower counts have ceased prior to the end of the coho salmon run due to high water events that created poor viewing conditions (Table 1; Jones *In prep*). Run strength of coho salmon in the Unalakleet River drainage has varied annually as indicated by past tower counts and by commercial and subsistence catches. Total escapement counts past the North River counting tower have varied from 2,966 fish in 2002 to 19,189 fish in 2005. Total subsistence and commercial harvests have also varied substantially over the past 10 years (Table 1).

This project was initiated in 2004 and results from that year indicated that the North River tower count project may provide an adequate index of the coho salmon return in the Unalakleet River drainage (Joy et al. 2005). Although North River coho salmon were smaller, on average, than those that migrated up the mainstem of the Unalakleet, run timing between the two systems did not differ significantly. The length and age distributions in both systems did not differ significantly and both runs were characterized by an early run of small age 1.1 coho salmon and a later run characterized by larger fish with almost half being age 2.1. Earlier running fish migrated into all tributaries of the drainage where as later running coho salmon were concentrated in the mainstem of the Unalakleet River, mostly in a portion between the Chiroskey River and the North Fork of the Unalakleet (Joy et al. 2005). A total of 11,187 coho salmon were estimated past the North River counting tower over the course of the 2004 run, and a population estimate of 73,582 coho salmon (95% credibility interval = 54,040–114,600) was generated for the entire Unalakleet River drainage (Joy et al. 2005). The 2004 experiment was replicated in 2005 and is planned to continue in 2006 to determine if the North River counting tower project provides a consistent indicator of timing and run strength of coho salmon returning to the Unalakleet River. This report summarizes results from the second year of this 3-year study.

OBJECTIVES

The objectives of this study in 2005 were to:

1. Estimate the proportions of the coho salmon escapement migrating up the mainstem Unalakleet, North, Chiroskey, and Old Woman rivers, and the North Fork of the Unalakleet River, and into all waters designated Federal Wild and Scenic rivers such that the estimates were within 7.5 percentage points of the actual values 90% of the time;

2. Estimate the abundance of coho salmon escaping into the Unalakleet River drainage such that the estimate was within 35% of the actual value 90% of the time;

3. Estimate the age, sex and length composition of the coho salmon escapement into the Unalakleet and the North rivers such that all estimated proportions were within 10 percentage points of the true values 95% of the time; and,
4. Document the locations of coho salmon spawning areas throughout the Unalakleet River drainage, including the Federal Wild and Scenic River portion of the river.

A project task was to estimate the abundance of coho salmon migrating through the Federal Wild and Scenic portion of the Unalakleet River, which is defined as the portion of the mainstem Unalakleet River above the confluence with the Chiroskey River.

METHODS

This study used radiotelemetry and mark-recapture techniques to estimate drainage-wide abundance and spawning distribution of coho salmon. Abundance was estimated using a Petersen-type two-sample mark-recapture experiment for a closed population (Seber 1982). The first sample consisted of coho salmon being captured and marked using radio tags in the mainstem Unalakleet River below the confluence with the North River. The second sample consisted of the total number of coho salmon that were counted past the North River counting tower. Radio-tagged coho salmon that passed the North River tower served as marked fish in the second event. All radio-tagged coho salmon were sampled for age, sex, and length (ASL) data, and ASL sampling was also conducted above the North River tower and in the Unalakleet River upstream from the capture site (referred to below as "upriver sampling") to evaluate mark-recapture assumptions of equal probability of capture for all fish. The spawning distribution of coho salmon was estimated by apportioning the total abundance estimate based on the proportion of radio-tagged fish in that area.

CAPTURE

Coho salmon were captured primarily by beach seining. Capture for radio-tagging occurred at a single site approximately 5 km upstream from the mouth of the Unalakleet River and 3 km downstream of the mouth of the North River (Figure 2). This tagging location was upstream from the commercial fishery and the majority of the subsistence effort, and downstream from the majority of the sport fishing effort. The beach seine was 150 ft long and 8 ft deep with 2 $^3/_4$ in mesh. A drift gillnet was used to capture coho salmon on September 16 (the last day of tagging) as water levels had risen too high for seining. The gillnet was 100 ft long, 33 panels deep (approximately 15 ft) and had 5 $^1/_2$ in mesh (bar measure).

The seine was operated by a crew of four persons utilizing an 18 ft jet-powered skiff. Two people stood and anchored one end of the seine off the bank of the river while the other two crew members in the skiff deployed the seine perpendicular to the bank, looping it downstream and returning back to the bank. The two ends of the seine were then pursed together and brought onshore by pulling in both ends of the seine by hand.

We anticipated little potential for sampling bias using these procedures because the seine reached across at least 80% of the river and unfished waters tended to be shallow and rapid.

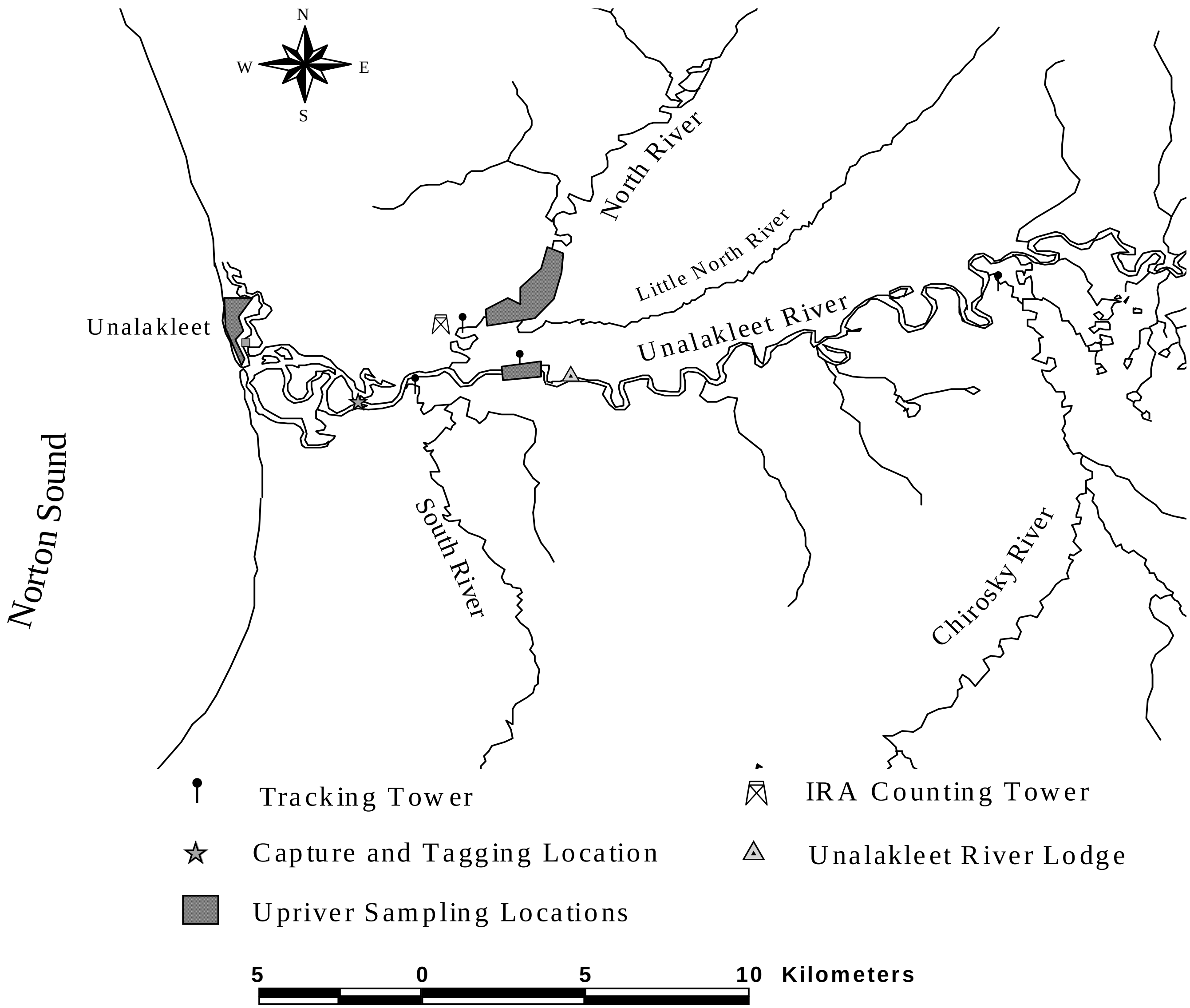

Figure 2.–Coho salmon capture and tracking station locations and North River counting tower site in the Unalakleet River drainage, 2005.

Standardized fishing for coho salmon began on July 20. Fishing continued until catches had fallen off to less than two fish per day for several days. The final day of fishing was September 16. Fish capture for radio-tagging occurred four days each week (Monday, Tuesday, Thursday and Friday). Sampling was conducted during a morning shift, approximately 0900-1300 hours, and an evening shift, approximately 1800-2200 hours. Initially, four seine hauls were made during each shift (total of eight per day). When fishing was slow, an extra seine haul was added on each shift. A 15 minute break was taken between seine hauls in the same stretch of water. If the second haul could be performed 50 to 100 meters below where the first seine haul was performed, then seine hauls were performed without a break.

TAGGING

After capture, coho salmon were placed in a large holding tub or were left in the beach seine while it was pursed up which acted as a net pen. All captured coho salmon were marked with an operculum punch unique to the periods corresponding to the expected quintiles of the run (Table 2). The sex of each coho salmon was determined by external characteristics and the fish were measured to the nearest 5 mm mid-eye fork (MEF) length.

Table 2.–Unalakleet River coho salmon radio-tagging goals, 2005.

Date	Number of Radio Tags Deployed	Cumulative No. of Tags Deployed	Operculum Punch Pattern
7/14-8/9	60	60	Left diamond
8/10-8/16	60	120	Left tear drop
8/17-8/23	60	180	Left heart
8/24-8/30	60	240	Left rectangle
8/31-9/30[a]	60	300	Left circle

[a] Anticipated end date; last day of tagging was 9/16.

A proportion of the coho salmon caught received a Model Five pulse encoded transmitter made by ATS[1]. Each radio-tag was distinguishable by its frequency and encoded pulse pattern. Fifteen frequencies spaced approximately 10 kHz apart in the 148-149 MHz range with 20 encoded pulse patterns per frequency were used for a total of 300 uniquely identifiable tags. Transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 24 g in air, and had a 30-cm external whip antenna. These radio tags were inserted through the esophagus and into the upper stomach of the fish using a 45-cm polyvinyl chloride (PVC) tube with a diameter equal to that of the radio tags. The end of the PVC tube was slit lengthwise to allow for the antenna end of the radio transmitter to be seated into the tube and held in place by friction. The radio transmitters were pushed through the esophagus and seated using a PVC plunger, slightly smaller than the inside diameter of the first tube, such that the antenna end of the radio tag was 0.5 cm beyond the base of the pectoral fin.

Each radio-tagged coho salmon was also tagged with a uniquely numbered spaghetti tag constructed of a 5-cm section of blue tubing shrunk onto a 38-cm piece of 80-lb monofilament. The monofilament was sewn through the musculature of the fish 1-2 cm ventral to the insertion of the dorsal fin between the third and fourth fin rays from the posterior of the dorsal fin. This

[1] Advanced Telemetry Systems, Isanti, Minnesota. Use of this company name does not constitute endorsement, but is included for completeness.

tag was used to help identify spawning fates of those fish that had lost their radio tag or were later harvested or recovered during upriver seining. After handling, the radio-tagged coho salmon were placed into quiet backwater areas upstream of the capture area for recovery. The entire handling process required approximately 2-3 min per fish.

Both the radio and spaghetti tags were labeled with return information to facilitate identification of the final fates of all fish (i.e., harvested in sport, commercial or subsistence fishery). Flyers describing the project and how to return the tags were posted in public locations throughout Unalakleet and with the local sport fish guiding services. To avoid fishers targeting the tagged fish no lottery or other monetary compensation was awarded for return of the tags.

ADF&G-CFD has operated a set gillnet test fishery in the Unalakleet River since 1981. The historic average run timing of coho salmon through this test fishery was used to develop the tagging schedule for distributing radio tags in proportion to run strength throughout the duration of the run (Figure 3). Tagging goals coincided with twentieth percentile increments of the average run timing pattern to ensure that run size was examined on a fine enough scale to adjust tagging rates if necessary (Table 2). A systematic sampling approach (x number of fish tagged per sampling day) was used to meet the tagging goals. Based on average run timing, the initial tagging schedule was to deploy 10 tags between July 20 and July 23, 5 tags per sampling day from July 25 through August 9 (50 tags total), 15 tags per sampling day from August 11 through August 30th (190 tags total), 10 tags per sampling day from September 1 through September 2 (20 tags total), 5 tags per sampling day from September 5 through September 6 (10 tags total) with the last 30 tags being distributed from September 8 through the end of the project.

UPRIVER SAMPLING

Every Wednesday and Saturday from July 20 through September 16, seining was conducted in the Unalakleet River upstream from the North River confluence and in the North River upstream from the counting tower (Figure 2). Both rivers were sampled on each day, one river in the morning and one in the afternoon and then reversing the order on the following sampling day. Four seine hauls were made in each area on each day. In both areas, the initial objective was to find one or more sites that were suitable for seining. After locating a site, the primary objective was to collect a systematic sample of coho salmon throughout the run to estimate ASL composition. Criteria for a “suitable” site included: 1) moderate to slow current velocity; 2) a river width sufficiently narrow so that the seine could cover most of the channel; 3) free of snags and large rocks; 4) an adequate beach to “land” the seine; and, 5) coho salmon were successfully captured at the site. In the Unalakleet River, the section of river that was sampled was approximately 1 km below the Unalakleet River Lodge (Figure 2). In the North River, the section of river that was initially used was 4 km above the counting tower. These sections were chosen for investigation because they met the criteria for a suitable seining area and were located a moderate distance upstream from the marking site which allowed marked fish to recover from any handling effects and allowed marked and unmarked fish to mix between capture events. During the last four weeks of upriver sampling in the North River, fish were no longer holding in this particular section of river. Therefore, new locations were used that were upriver of the initial sampling site where fish were holding and seining was possible.

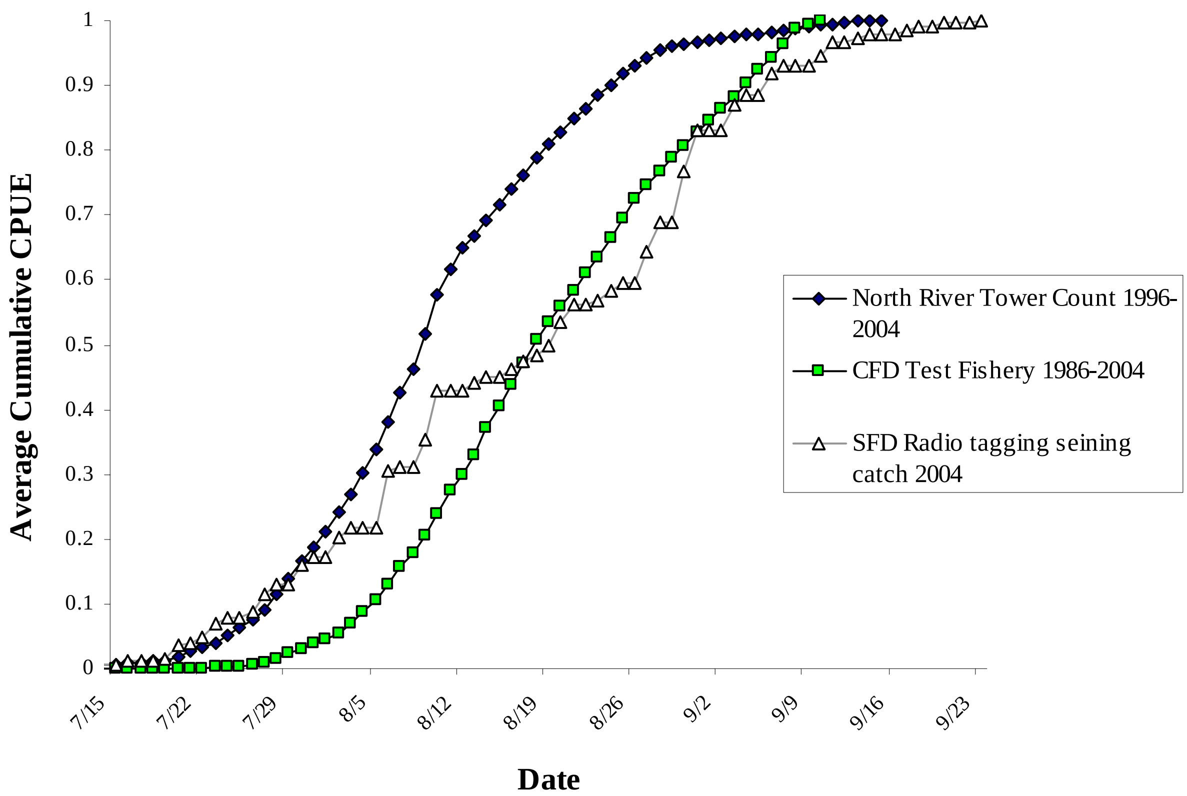

Figure 3.–Average cumulative CPUE of Unalakleet River coho salmon at ADF&G-CFD test fishery from 1986 through 2004, the North River counting tower from 1996 through 2004, and from the 2004 seining catch of the Sport Fish Division (SFD) radio-tagging project.

Upriver seining procedures were similar to those previously described. All coho salmon captured during upriver seining were given an adipose fin clip to uniquely identify them as being captured upriver. All captured fish were inspected for tags and operculum punches and sampled for length, sex, and age. To determine age, three scales were removed from the left side of each fish approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin and placed on gum cards. In the postseason scale impressions were made on acetate cards and viewed at 100X magnification using equipment similar to that described by Ryan and Christie (1976). Ages were determined from scale patterns as described by Mosher (1969).

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio-tagged coho salmon were tracked and spawning destinations were discerned through the use of four stationary radio-tracking towers and four aerial radio-tracking surveys. One tower was located 200 yards up the South River, one was located at the North River counting tower, one was located on the Unalakleet River several kilometers above the confluence with the North River and one was located 100 yards up the Chiroskey River (Figure 2).

Each tracking station included one gel-cell, deep-cycle battery, an 80-watt solar array, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, an antenna switching box, a weather-proof metal housing box, and two, four-element Yagi antennas (one aimed upstream and the other downstream). The receiver and DCC II were programmed to scan through the frequencies at three-second intervals receiving with both antennas simultaneously. When a radio signal of sufficient strength was encountered the receiver paused for six seconds, at which time the data logger recorded the frequency, code, signal strength, date, and time for each antenna. Cycling through all frequencies required 2-15 min depending on the number of active tags in reception range. Data were downloaded onto a portable computer every seven to 10 days.

The distribution of radio-tagged salmon throughout the Unalakleet River drainage was further determined by aerial tracking from fixed-wing aircraft and from weekly boat surveys to: 1) locate tags in areas other than those monitored with tracking stations; 2) locate fish that the tracking stations failed to record; and, 3) validate that a fish recorded on one of the data loggers did migrate into a particular stream. Boat surveys were restricted to the mainstem of the Unalakleet River upstream to the Chiroskey River and up the North River to the upriver sampling site. Aerial surveys performed on August 13, September 1, September 20 and October 15 included all tributaries and tertiary streams.

DATA ANALYSIS

Fates of Radio-Tagged Fish

For data analysis, each fish was assigned a “final location” based on the furthest upriver location at which it was located by air or tracking station. Each radio-tagged fish was assigned 1 of 7 possible fates based on information collected from aerial tracking surveys and from stationary data logging stations.

Fate 1) In the North River – a fish that was determined to have entered the North River and passed the North River tracking station.

Fate 2) In the Upper Unalakleet River/Tributaries – a fish that was determined to have migrated into one of the tributaries of the Unalakleet River other than the North River and including the South River, the Chiroskey River, the North Fork, the 10 mile River, and the Old Woman River. Additionally, the section of the Unalakleet River that is above the Old Woman River confluence was included in this group based on the GIS analysis and the similarity of these fish to the rest of the tributary destined fish.

Fate 3) In the Mainstem Unalakleet River – a fish that was determined to have migrated into the Unalakleet River upstream of the North River and was never detected in any tributary or above the confluence with the Old Woman River.

Fate 4) Dead/Regurgitated – a fish that did not migrate past the confluence of the North and Unalakleet rivers and was assumed to have died and/or regurgitated its radio tag.

Fate 5) Harvested below tracking stations – a fish that was determined to have been harvested by a commercial, subsistence or sport fisherman downstream from the North, Unalakleet, or South River tracking stations.

Fate 6) Harvested above tracking stations – a fish that was determined to have been harvested by a subsistence or sport fisherman upstream from the North, Unalakleet, or South River tracking stations.

> ***Fate 7)*** Backed Out/Unknown – a fish that was tagged and was never recorded at any tracking stations or on any aerial or boat surveys or a fish that was recorded at or below the tracking stations but not having passed the stations after which it was no longer detected by either tracking stations or boat and aerial surveys..

Radio-tagged coho salmon given fates 1-3, and 6 were used to estimate abundance, those with fates 1-3 were used to describe spawning distributions, and those with fates 4, 5, and 7 were culled from all analyses.

Mark-Recapture Experiment

This experiment was designed so that Chapman's modification to the Petersen estimator (Chapman 1951) could be used to estimate abundance, contingent on the results of diagnostic testing for equal probability of capture (described below).

Conditions for a Consistent Petersen Estimator

For the estimate of abundance from this mark-recapture experiment to be unbiased, certain assumptions needed to have been fulfilled (Seber 1982). The assumptions, expressed in terms of the conditions of this study, respective design considerations, and test procedures are listed below. To produce an unbiased estimate of abundance with the generalized Petersen model, Assumptions I, II and III, and one of the conditions of Assumption IV must have been met.

<u>Assumption I: The population was closed to births, deaths, immigration and emigration.</u>

This assumption was violated because harvest of some fish occurred between events. However, we assumed that marked and unmarked fish were harvested at the same rate. Thus, provided there was no immigration of fish between events, the estimate was unbiased with respect to the time and area of the first event (estimate of inriver abundance, not escapement). Sampling in both events encompassed the majority of the run. Any immigration of coho salmon past the capture site prior to or after the marking event was assumed to be negligible.

<u>Assumption II: Marking and handling did not affect the catchability of coho salmon in the second event.</u>

There was no explicit test for this assumption because the behavior of unhandled fish could not be observed. However, to minimize any handling effects, the holding and handling time of all captured fish was minimized. Any obviously stressed or injured fish were not radio-tagged. Radio-tagged fish that were not detected past either the North River tracking station or the mainstem Unalakleet River tracking station upstream of the confluence with the North River were removed from the experiment. It was assumed that if a fish was able to migrate this distance, then there were no effects from handling and tagging.

<u>Assumption III: Tagged fish did not lose their tags between the tagging site and their spawning destination.</u>

A combination of stationary tracking stations and aerial and boat tracking surveys were used to identify radio tags that were expelled. All fish determined to have regurgitated their tags were culled from the analyses.

Assumption IV:

1) All coho salmon had the same probability of being caught in the first sampling event;
2) All coho salmon had the same probability of being captured in the second sampling event; or,
3) Marked fish mixed completely with unmarked fish between sampling events.

It was considered likely that tagging rates would vary and possible that fishing effort would vary. If discrete coho salmon spawning aggregations in the Unalakleet River entered the river with different run timing schedules, varied tagging rates and fishing effort could result in biased estimates of the proportion of the run that migrated past the North River counting tower and proportion estimates for fish spawning in other areas of the drainage.

Equal probability of capture was evaluated by size and temporally. Coho salmon were captured and tagged over the entire span of the run. Radio tags were implanted into coho salmon of various sizes. Length, date, and time of release were recorded for all tagged fish. The North River tower counts occurred over the span of the run. Age, sex, and length data were collected from the samples of fish past the North River tower and in the mainstem Unalakleet River above the confluence of the North River. The procedures to evaluate equal probability of capture across size categories are described in Appendix A1, as well as corrective measures (stratification), based on diagnostic test results to minimize bias in estimates of abundance and composition. Due to potential errors in correctly identifying the gender of coho salmon at the tagging site, sex ratios of tagged fish and fish spawning in the North River were not compared.

To further evaluate the three conditions of Assumption IV, contingency table analyses recommended by Seber (1982) were used to detect significant temporal violations of assumptions of equal probability of capture. These diagnostic tests and recommendations for selecting the correct model to calculate an unbiased estimate of abundance are described in Appendix A2.

AGE, SEX, AND LENGTH COMPOSITION AND SPAWNING PROPORTIONS

The numbers of coho salmon by length, age, or sex group *k* were estimated within a major spawning destination *d* where *d* indicates either North River or mainstem Unalakleet River stocks and then combined arithmetically. Composition proportions were first estimated using:

$$\hat{p}_{kd} = \frac{n_{kd}}{n_d} \tag{1}$$

where:

$\hat{p}_{kd} =$ estimated proportion of coho salmon in group *k* at destination *d*;

$n_{kd} =$ number of sampled coho salmon in group *k* at destination *d*; and,

$n_d =$ total number of coho salmon sampled at destination *d*.

Estimates of total numbers of salmon in group *k* within each system of *d* were calculated:

$$\hat{N}_{kd} = \hat{N}_d \, \hat{p}_{kd} \tag{2}$$

where $\hat{N}_d$ = N_{NR}, the total North River tower count estimate, where *d* indicates North River, and, $\hat{N}$ - N_{NR} where *d* indicates mainstem Unalakleet River.

These estimates were summed across destination to calculate the estimated number of coho salmon in group *k* in the escapement:

$$\hat{N}_k = \sum_{d=1}^{2} \hat{N}_{kd} \ , \tag{3}$$

and the proportion of coho salmon in group *k* was estimated:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N} \, . \tag{4}$$

Variance for the estimates of $\hat{N}_k$ and $\hat{p}_k$ were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for $\hat{N}_k$ and $\hat{p}_k$, which were calculated using equations (1-4) were generated by collecting 1,000 simulated values of $\hat{N}_k$ and $\hat{p}_k$ from simulated values of equation parameters. The simulated values were modeled from observed data using multinomial models within destination for composition proportions. Simulated values for $\hat{N}$ were calculated using the equations described in Darroch (1961) after using multinomial models within each first event stratum to model the observed distributions marked fish among recaptures within second event temporal strata and unrecaptured fish.

Variances estimates were calculated from simulated values in the posterior distribution for each abundance or composition parameter estimate $\hat{z}$ using:

$$\bar{z}^* = \frac{\sum_{b=1}^{1,000} \hat{z}_b^*}{1,000} \text{ and,} \tag{5}$$

$$V\hat{a}r(\hat{z}) = \frac{\sum_{b=1}^{1,000} (\hat{z}_b^* - \bar{z}^*)^2}{1,000 - 1} \tag{6}$$

where $\hat{z}_b^*$ is the *b*th simulated value of $\hat{z}$.

Adjustments for unequal probability of capture during the first (marking) event were necessary to calculate unbiased estimates of proportions of coho salmon migrating to different spawning destinations. Estimates of abundance of coho salmon passing the marking site within each of the first event temporal strata described above were calculated using the methods described in Darroch (1961). Estimates of spawner proportions were calculated for each first event temporal strata using formulae similar to those described above for composition estimates. Estimates of spawner proportions for the entire run were calculated by combining estimated first event stratum proportions weighted by estimated first event stratum abundance estimates. Variances for these parameter estimates were estimated using Markov Chain Monte-Carlo techniques similar to procedures described for estimates for composition.

Mean length at age within sex and/or spawning destination categories and its sampling variance were estimated using standard sample summary statistics (Cochran 1977).

Data from capture, tagging, and radiotelemetry used to estimate parameters of the coho salmon abundance and length, age, and sex compositions in this study were entered into Excel spreadsheets for analysis and archival (Appendix B).

RESULTS

TAGGING AND FATES OF RADIO-TAGGED COHO SALMON

Between July 20 and September 16, a total of 1,397 coho salmon were captured at the lower river tagging site and 287 radio transmitters were deployed. The fish ranged in length from 295 to 670 mm MEF (Figure 4; Table 3).

Of the 287 salmon that were radio-tagged, 256 continued upstream migration past the tracking towers on the Unalakleet and North rivers. Sixteen radio-tagged coho salmon were harvested, although three were harvested after passing tracking stations. Six radio-tagged coho salmon either died or regurgitated their radio tag shortly after handling. Of the 16 fish assigned to the backed out/unknown fate, seven radio-tagged coho salmon likely backed out of the drainage and another nine radio coho salmon could not have an accurate fate assigned.

DISTRIBUTION OF RADIO-TAGGED COHO SALMON

Radio-tagged coho salmon were detected in all portions of the Unalakleet River drainage including the South, North, Chiroskey, 10 Mile, North Fork Unalakleet, and Old Woman rivers (Figure 5; Table 4). The area with the highest concentration of coho salmon as determined by aerial radio-tracking surveys was the section of the Unalakleet River that lies above the Chiroskey River and below the North Fork.

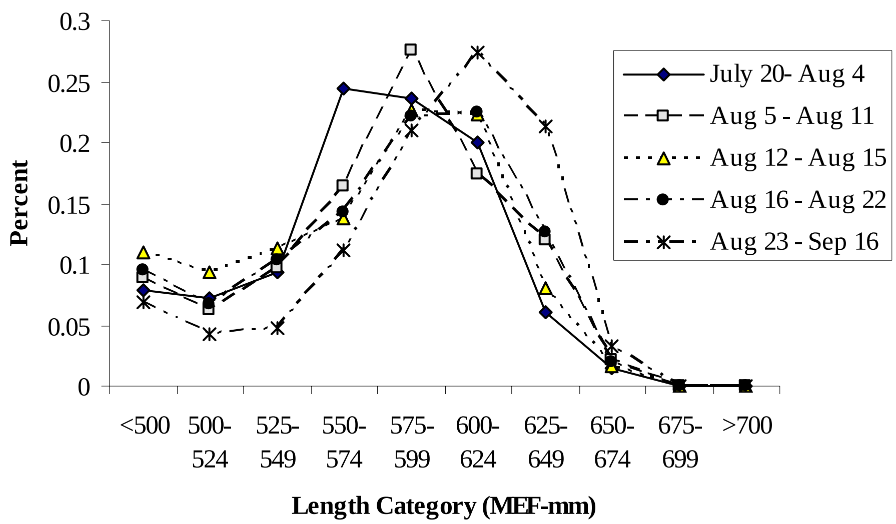

Figure 4.–The length distribution of Unalakleet coho salmon captured at the tagging site for each of the five run quintiles, 2005.

Table 3.–Catch and length statistics for male and female coho salmon sampled at the downriver tagging location and in the North and mainstem Unalakleet rivers, 2005.

Statistic	Downriver Tagging Location		Upriver Sampling	
	All Fish	Tagged Fish	Unalakleet River	North River
Number caught				
All	1390	256	682	654
Male	709	121	366	364
Female	681	135	316	290
Mean Length (mm)				
All (SD)	576.35 (46.70)	590.46 (39.11)	572.34 (44.66)	566.82 (42.86)
Male (SD)	579.91 (51.48)	594.49 (42.66)	573.80 (49.52)	567.95 (50.74)
Age 1.1		590.49 (44.17)	597.16 (39.61)	589.44 (41.51)
Age 2.1		603.79 (38.49)	600.59 (44.11)	584.24 (37.74)
Female (SD)	572. 02 (40.04)	587.12 (35.65)	567.01 (40.12)	563.44 (34.33)
Age 1.1		583.29 (33.11)	573.82 (57.56)	571.23 (32.84)
Age 2.1		599.09 (34.43)	573.79 (32.31)	570.36 (36.66)
Length Range				
All	365-675	460-665	400-655	410-655
Male	370-675	460-665	425-650	410-655
Female	365-660	465-665	400-655	420-650

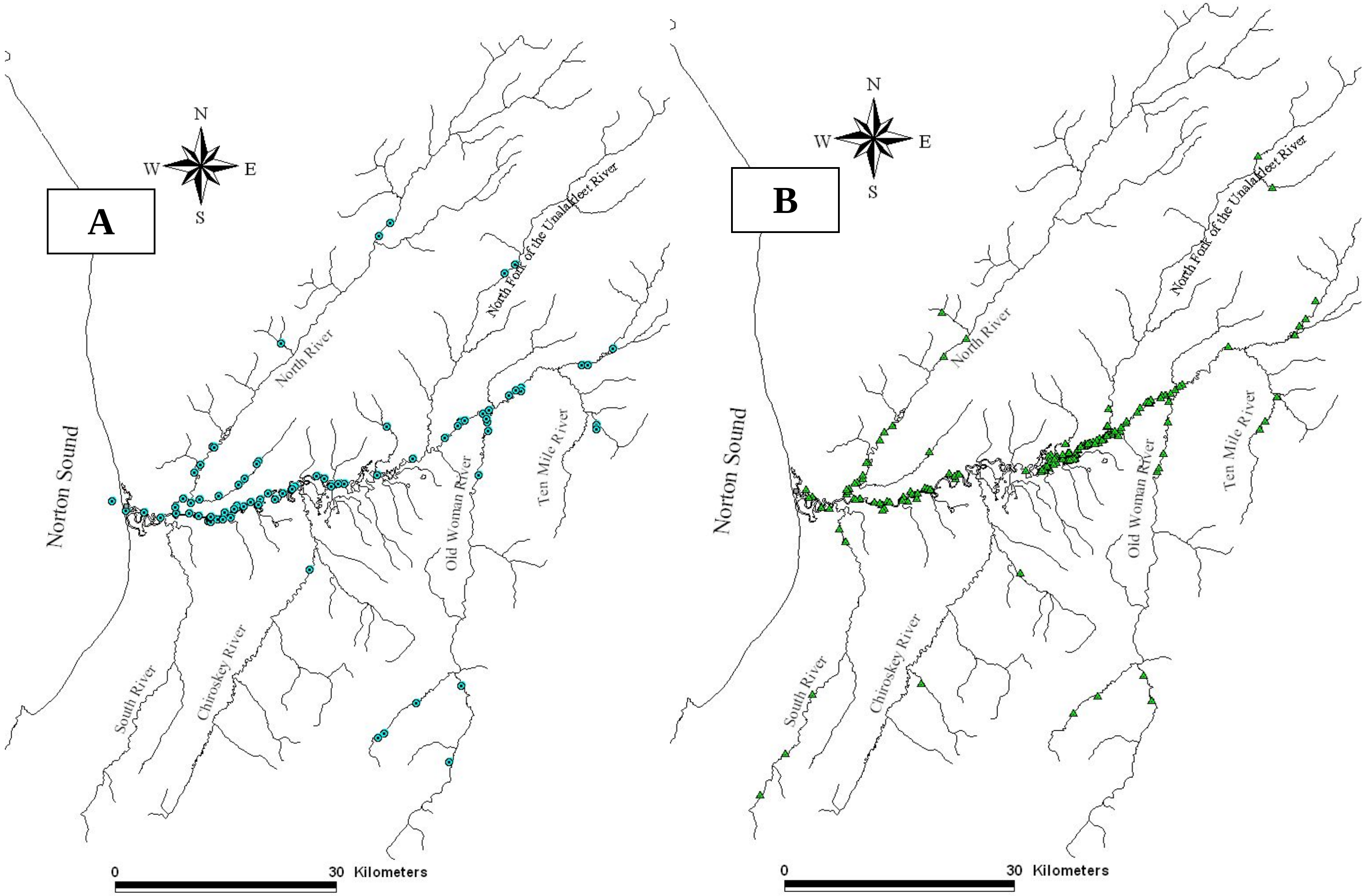

Figure 5.–Maps showing the farthest upstream locations of all radio-tagged coho salmon in the Unalakleet drainage, 2005. A shows the distribution of coho salmon that were radio-tagged on or before August 11 and B shows the distribution of coho salmon that were radio-tagged after August 11.

Table 4.–Fates of radio-tagged coho salmon in the Unalakleet River drainage, 2005.

General Fate[a]	Number of Radio Tags	Specific Fate	Number of Radio Tags
		North River	24
North River	31	Little North River	7
		Harvested in North River	0
		Upper Mainstem	20
		South River	3
Upper Unalakleet/ Tributaries	53	Chiroskey River	3
		North Fork Unalakleet	6
		Old Woman River	16
		10 Mile River	5
Mainstem Unalakleet	167		
Harvested above tracking tower on Unalakleet	3		
Total past tracking towers	**256**		
Dead or Regurgitated Tags	6		
		Sport fishery	7
Harvested below tracking towers	12	Subsistence fishery	1
		Unknown	4
Backed Out/Unknown	16		
Total that never passed tracking towers	**34**		

[a] A description of each fate is given in the Methods section.

Of the 256 radio-tagged coho salmon that passed the tracking stations and were located upriver, 31 migrated past the North River counting tower (hereafter referred to as *North River coho salmon*), 55 coho salmon migrated into other tributaries or migrated up the mainstem of the Unalakleet River above the Old Woman River (hereafter referred to as *upper Unalakleet/tributary coho salmon*), 167 coho salmon migrated up the mainstem of the Unalakleet River and remained in the section between the North River and the Old Woman River (hereafter referred to as *mainstem coho salmon*) and three migrated up the Unalakleet River but were harvested before reaching their spawning destination. When referring to *upper Unalakleet/tributary coho* and *mainstem coho* collectively they will be referred to as *Unalakleet coho salmon*. Estimated proportions of coho salmon migrating to these various portions of the drainage were 0.143 (SE=0.024) to the North River, 0.573 (SE=0.049) to the mainstem of the Unalakleet River below the Old Woman, and 0.284 (SE=0.040) to the upper Unalakleet and it's tributaries including 0.017 (SE=0.009) to the Chiroskey River, 0.092 (SE=0.022) to the Old Woman River, and 0.030 (SE=0.011) to the North Fork (Table 5; Figure 6). Of the tributary streams, the North River accounted for the largest proportion of radio-tagged fish that migrated upstream after capture (Figure 6). The estimated proportion of coho salmon that migrated into or through the Federal Wild and Scenic River portion of the river was 0.608 (SE=0.041).

MARK-RECAPTURE EXPERIMENT

Tests of Consistency

Tests for size biased sampling (Appendix A1) indicated that there was no significant difference in the length distribution of those radio-tagged coho salmon that migrated past the North River tower and the length distribution of all radio-tagged coho salmon (Marks vs. Recaptures; D=0.182, P=0.266: Figure 7). Thus, we found no evidence of second event size biased sampling. When the length distribution of radio-tagged coho salmon that migrated past the North River counting tower was compared with those salmon sampled in the North River (Recaptures vs. Captures; D=0.236, P=0.064), the marginal p-value indicated some potential for size bias sampling during the marking event. There was a significant difference in the length distribution of all radio-tagged coho salmon and the length distribution of those fish sampled above the North River counting tower (Marks vs. Captures; D=0.233, P=0.000). Based on the results of this indirect, but more powerful (larger sample sizes) diagnostic test and the results of theRecaptures vs. Captures test, it was concluded that size biased sampling did occur during the first event. The results of these tests indicated a Case III-type experiment (Appendix A1). Therefore lengths were pooled to estimate abundance, but only lengths from the second sample (upriver sampling) were used to estimate ASL compositions.

Diagnostic tests indicated only slight differences between the run timing of North River and Unalakleet River coho salmon (Figure 8; D=0.229, P=0.082). The run-timing of mainstem coho salmon and upper Unalakleet/tributary coho salmon were also compared (Figure 9), and there was a significant difference in run-timing of these two groups of fish (D=0.381, P<0.001) with the upper Unalakleet/tributary coho salmon entering the system significantly earlier than mainstem coho salmon.

Table 5–Estimated proportions of coho salmon entering the North River, the mainstem Unalakleet River, the Upper Unalakleet/ tributaries, the Chiroskey River, the Old Woman River, the North Fork Unalakleet River, and the entire Unalakleet drainage (excluding the North River), 2005. Standard errors for estimates are in parentheses.

Area	Proportion (SE)
North River	0.143 (0.024)
Mainstem Unalakleet	0.573 (0.047)
Upper Unalakleet/Tributaries	0.284 (0.040)
Chiroskey River	0.017 (0.009)
Old Woman River	0.092 (0.021)
North Fork	0.030 (0.011)
Entire Unalakleet	0.857 (0.023)
Federal Wild and Scenic portion of Unalakleet	0.608 (0.041)

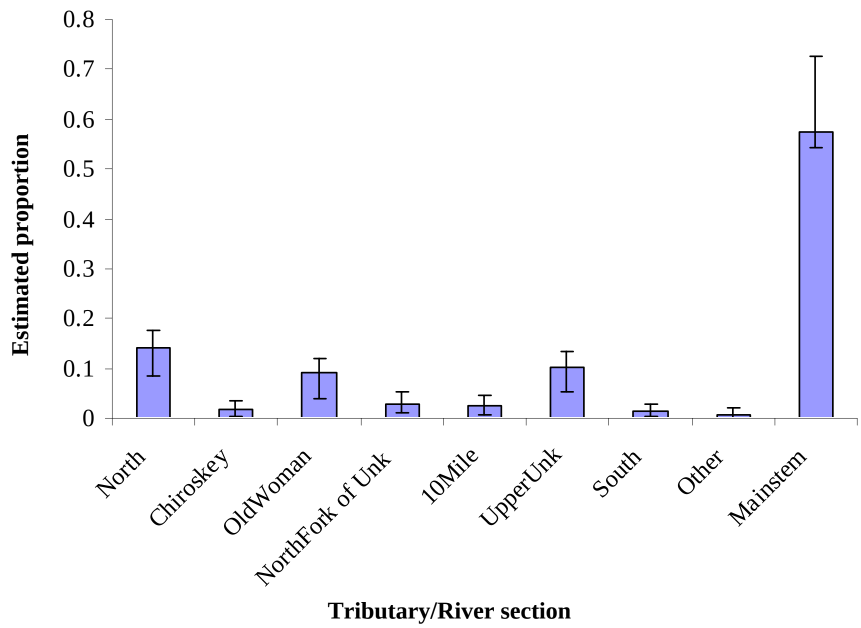

Figure 6.–The estimated proportional distribution of coho salmon in the Unalakleet River drainage in 2005. The Upper Unalakleet is defined in this report as the section of the Unalakleet River located above its confluence with the Old Woman River. The mainstem Unalakleet River is defined in this report as the section of the Unalakleet River located below its confluence with the Old Woman River. Error bars represent 95% confidence intervals.

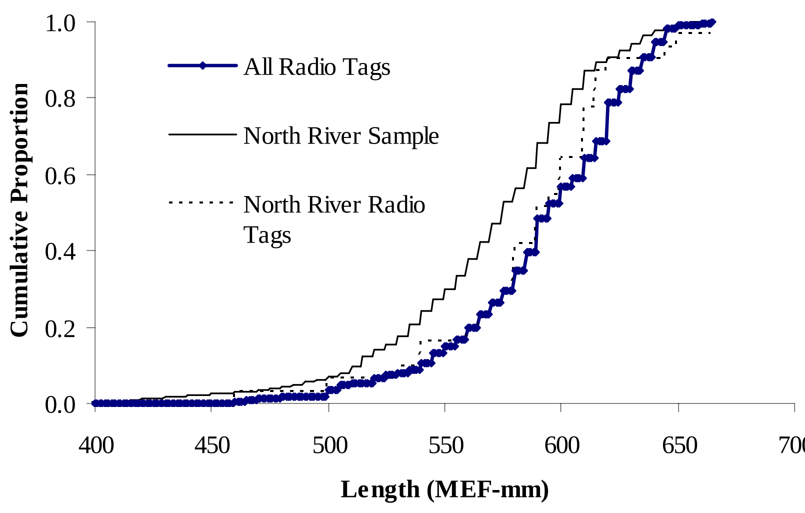

Figure 7.–Cumulative length frequency distributions of all radio-tagged fish, all fish sampled above the North River counting tower, and all radio-tagged fish migrating above the North River counting tower, 2005.

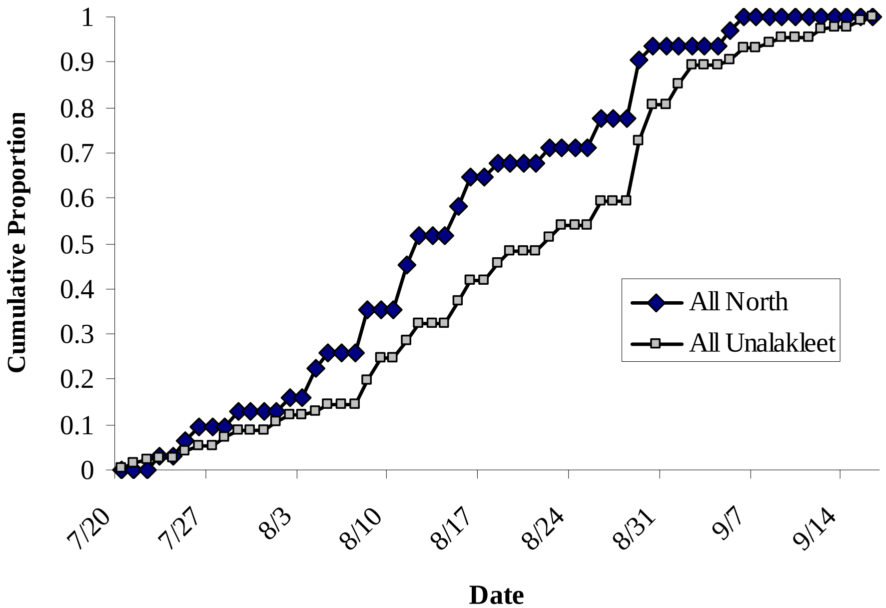

Figure 8.–Cumulative run timing past the capture site for radio-tagged coho salmon that migrated up the North River and up the Unalakleet River, 2005.

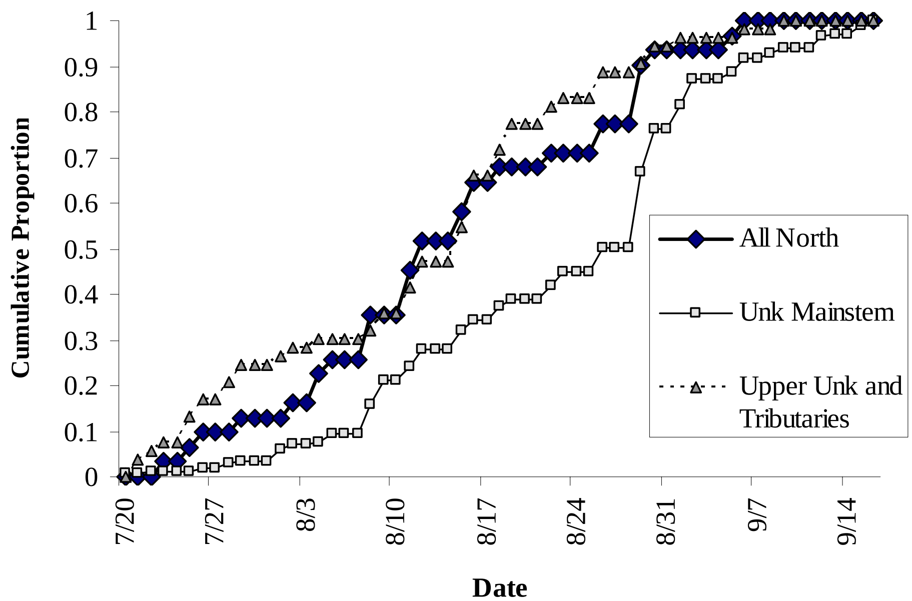

Figure 9.–Cumulative run timing past the capture site for three groups of coho salmon in the Unalakleet River drainage, 2005. North River coho salmon are those fish that migrated up the North River; Upper Unalakleet/Tributary coho salmon are those that migrated into tributaries other than the North River or migrated up the Unalakleet River past the Old Woman River confluence. Mainstem Unalakleet refers to those coho salmon that migrated up the Unalakleet River but never entered a tributary nor passed the confluence with the Old Woman River.

Temporal violations of equal probability of capture during the second event were explored using contingency table analyses (Appendix A2; Table 6). No significant difference was detected in the probability that a marked fish was recaptured during the second event between the five quintiles of the run when examining all radio-tagged salmon (χ^2 =5.537, P=0.237). The test to determine equal probability of capture during the first event throughout the five run quintiles was similarly non-significant (P=0.370).

Table 6.–Data used to test the assumption of equal probability of capture by time during the second event for all fish.

Date	Recaptured	Not Recaptured
7/20-8/04	7	29
8/05-8/11	7	35
8/12-8/15	4	20
8/16-8/22	4	31
8/23-9/17	9	110
Before 8/27	24	134
After 8/27	7	91

Until August 27 coho salmon were tagged in proportion to the daily catch and in accordance with historical run timing data. However, in the days immediately preceding the 27th it became apparent that the run was diminishing earlier than its historical average. In an effort to utilize all radio tags the sampling protocol was changed such that nearly every captured coho was radio-tagged to remain on the planned schedule of tag deployment. To determine if there was a temporal bias with regard to this change in tagging effort contingency table analysis was performed again with a 2x2 table using August 27 as the split days (Table 6). The results did indicate potential temporal bias during second event handling (P=0.055). A similar test run to detect temporal bias during the first event also detected significant temporal bias (P=0.012; Table 7). Additionally, the null hypothesis of the test for complete mixing (Appendix A2) was rejected (P<0.001).

Table 7.–Data used to test the assumption of equal probability of capture by time during the first event for all fish.

Date	Marked	Unmarked
Before or on 8/29	22	16,554
After 8/29	9	2,604

The diagnostic tests indicated that a partially stratified estimator (Darroch 1961) would be necessary to estimate abundance. First event sampling data were each stratified into two temporal strata; fish marked up to and including August 26 and fish marked August 27 and later. Second event sampling data were also stratified into two temporal strata; from tower counts and radio-tag recaptures up to and including August 29 and counts and recaptures from August 30 and later.

ABUNDANCE ESTIMATE

Two hundred fifty six radio-tagged coho salmon continued upstream migration past the tracking towers on the Unalakleet and North rivers and served as the first (marked) sample. A total of 19,189 coho salmon were counted past the North River counting tower (Jones *In prep*) and served as the second sample. Thirty-one radio-tagged coho salmon migrated past the North River counting tower and served as recaptures in the second sample. The estimated abundance of coho salmon that entered into the Unalakleet River drainage above the capture site was 134,531 fish (maximum likelihood SE=28,550; 95% credibility interval=111,800 to 223,500).

An approximate estimate of abundance of coho salmon migrating into the federal wild and scenic portion of the river was 81,798 (SE=22,070) fish. The estimate is approximate because coho salmon are harvested between the point for which abundance was estimated (capture and tagging site in the lower river) and the lower boundary of the wild and scenic portion of the river. Sport harvest of coho salmon is estimated from ADF&G Sport Fish Statewide Harvest Survey and those estimates were not available in time to accommodate the reporting schedule for this project. Because sport harvest was not subtracted from the total drainage abundance estimate prior to multiplying by the estimated proportion of coho salmon migrating through the Federal Wild and Scenic portion of the drainage, the resulting estimate of abundance of fish migrating through that portion of the drainage are biased high, but the bias is not likely to be greater than 5%.

ESTIMATION OF AGE-SEX-LENGTH COMPOSITION

Age, sex, and length compositions of the escapement were estimated from coho salmon sampled at the upriver sites on the North River and Unalakleet River. The length distribution of coho salmon sampled at each site was considered unbiased because a beach seine was used that caught coho as small as 295 mm MEF. However, the length distribution of coho salmon sampled at the upper site in the Unalakleet River was significantly different than the length distribution of those fish sampled above the North River counting tower ($D=0.173$, $P<0.001$; Figure 10). All 553 coho salmon that were successfully aged were either age-2.1 or age-1.1 (Table 8). There were slightly more age 1.1 coho for males and females in both drainages (Table 9).

Estimates of mean length of male and female coho salmon in the North River and Unalakleet River also substantiated size differences between the two drainages (Table 3). The average size of male coho salmon in the North River was 568 mm MEF (SD=51) and the average size of female coho salmon was 563 mm MEF (SD=34). The average size of male coho salmon sampled in the Unalakleet River was 574 mm MEF (SD=50) and the average size of female coho salmon was 567 mm MEF (SD=40). The proportion of male coho salmon in the North River sample was 0.56 (SE=0.019), and the proportion of male coho salmon in the Unalakleet River was 0.54 (SE=0.019; Table 9).

There was also evidence of temporal differences in size. The size distribution of coho salmon handled at the capture location during the first two quintiles of the run (July 20 - August 12) was significantly smaller than the coho salmon handled during the last three quintiles of the run (August 13 - September 16; D-statistic=0.117, $P<0.01$; Figure 4). This difference was significant for males at the 10% level ($D=0.090$, $P=0.10$) and highly significant for females ($D=0.188$, $P=0.00$).

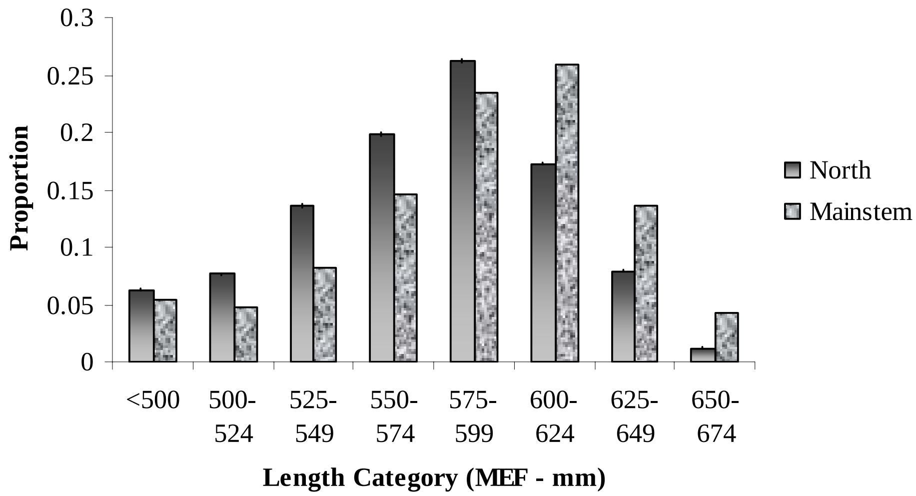

Figure 10.–Size distribution of coho salmon sampled in the Unalakleet and North rivers, 2005.

Table 8.–Estimated age, sex, and length composition of the coho salmon escapement in the Unalakleet River drainage, 2005.

Sex/Age Category	$\hat{p}_k$	SE($\hat{p}_k$)	$\hat{N}_k$	SE($\hat{N}_k$)
Male	0.539	0.017	72,579	15,510
1.1	0.661	0.036	47,989	10,850
2.1	0.339	0.036	24,590	6,028
Female	0.461	0.017	61,952	13,760
1.1	0.546	0.037	33,795	8,132
2.1	0.454	0.037	28,157	6,704

Table 9–The proportion of male and female coho salmon that migrated up the North and Unalakleet rivers that were age-1.1 and -2.1 in 2004. Standard errors for estimates are in parentheses.

Sex	River	Age 1.1	Age 2.1
Male	North River	0.60 (0.037)	0.40 (0.037)
	Unalakleet River	0.67 (0.041)	0.33 (0.041)
	Entire Drainage	0.66 (0.036)	0.34 (0.036)
Female	North River	0.53 (0.047)	0.47 (0.047)
	Unalakleet River	0.55 (0.042)	0.45 (0.042)
	Entire Drainage	0.55 (0.037)	0.45 (0.037)

Proportions of age 1.1 and 2.1 coho salmon during the first two quintiles of the run were similar to the last three quintiles (Figure 11). Proportions were not significantly different for the North River (χ^2=0.18, P=0.668) or for the Unalakleet River (χ^2=1.38, P=0.24). Additionally, for male coho salmon, proportions were not significantly different in the North River (χ^2=1.14, P=0.28), but were in the Unalakleet River (χ^2=5.08, P=0.02). For female coho salmon, proportions were not significantly different in the North River (χ^2=0.68, P=0.41) nor in the Unalakleet River (χ^2=0.003, P=0.95). There was no apparent difference in the spawning location of age-1.1 and-2.1 coho salmon (Figure 13).

Age-2.1 coho salmon were, on average, slightly larger than fish age-1.1 with the exception of females in the North River (Figure 12). However, using paired two-tailed t-tests, the differences were not significant at the 0.05 level.

DISCUSSION

SPAWNING DISTRIBUTION AND RUN TIMING

Radio-tagged coho salmon were detected in every major tributary and in many tertiary streams over the course of the four aerial survey flights. Most coho salmon were detected in the section of the Unalakleet River above the Chiroskey River and below the North Fork. Only coho salmon captured in the last three quintiles of the run were detected in this section of the river (Figure 5). This pattern also occurred in 2004 (Joy et al. 2005), and Unalakleet residents report springs in the area that may explain the preference for these spawning destinations late in the season.

While the pattern of coho salmon spawning in this area arriving later at the capture site was consistent between 2004 and 2005, the pattern of tributary spawners and when they arrived was less consistent between years. In 2004 most tributary spawners arrived during the first two quintiles of the run while very few tributary spawners arrived later in the run (Joy et al. 2005). In contrast, the 2005 coho run had tributary spawners arriving both in the early and the later part of the run (Figure 5), although tributary spawners did have significantly earlier run timing than mainstem spawners (Figure 10).

The 2005 Unalakleet coho salmon run differed from the 2004 run in the lack of evidence indicating two overlapping runs. The 2004 coho salmon run was characterized by two somewhat distinct groups migrating into the Unalakleet River drainage with overlapping run timing. Coho salmon migrating into the drainage between July 19 and August 13, 2004 were on average smaller, mostly age-1.1 and were destined for tributaries and the upper portion of the Unalakleet drainage. Coho salmon migrating into the drainage after August 14 were on average, larger, had an even proportion of age-1.1 and -2.1 fish and were mostly limited to the portion of the Unalakleet River below the North Fork. These differences were significant for both males and females and were not likely to be related to the earlier run timing of males (Joy et al. 2005). In 2005, tributary spawners again had a later run timing than did mainstem spawners (Figure 10) and later running fish were significantly larger than earlier running fish (Figure 4). However, there were no apparent differences in age composition between the early and later portions of the run as seen in 2004 (Figure 11; Joy et al. 2005). Despite the later run timing of mainstem spawners seen in both years, 2005 saw far more tributary spawning fish in the later part of the run (Figure 5) than was seen in 2004 (Joy et al. 2005).

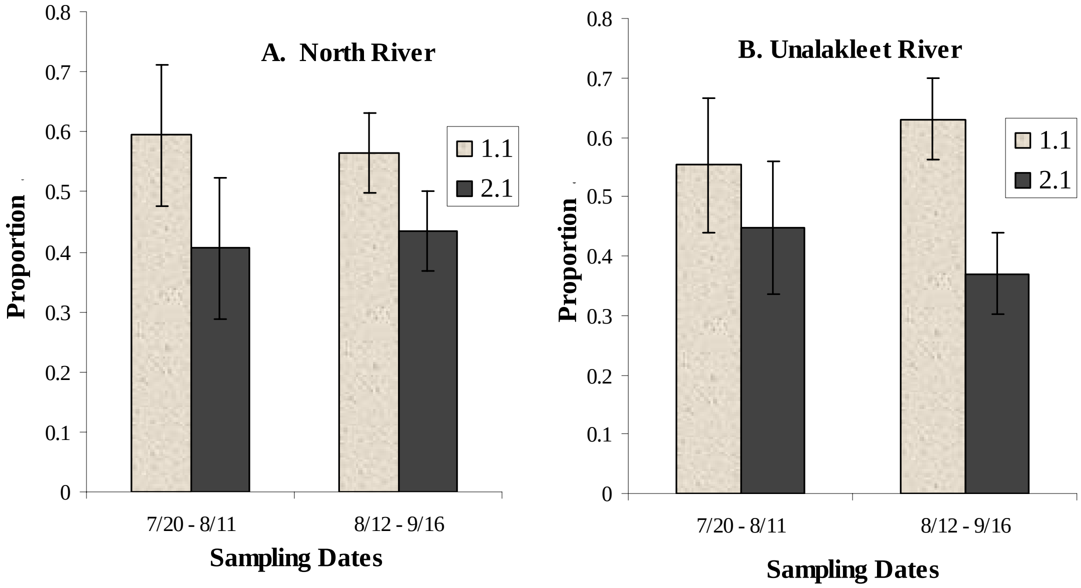

Figure 11.–The proportion of fish age-1.1 and -2.1 in the North (A) and Unalakleet rivers (B) during the first two run quintiles (July 20 – August 11) and the last three run quintiles (August 12 and September 16), 2005. Error bars represent 95% confidence intervals.

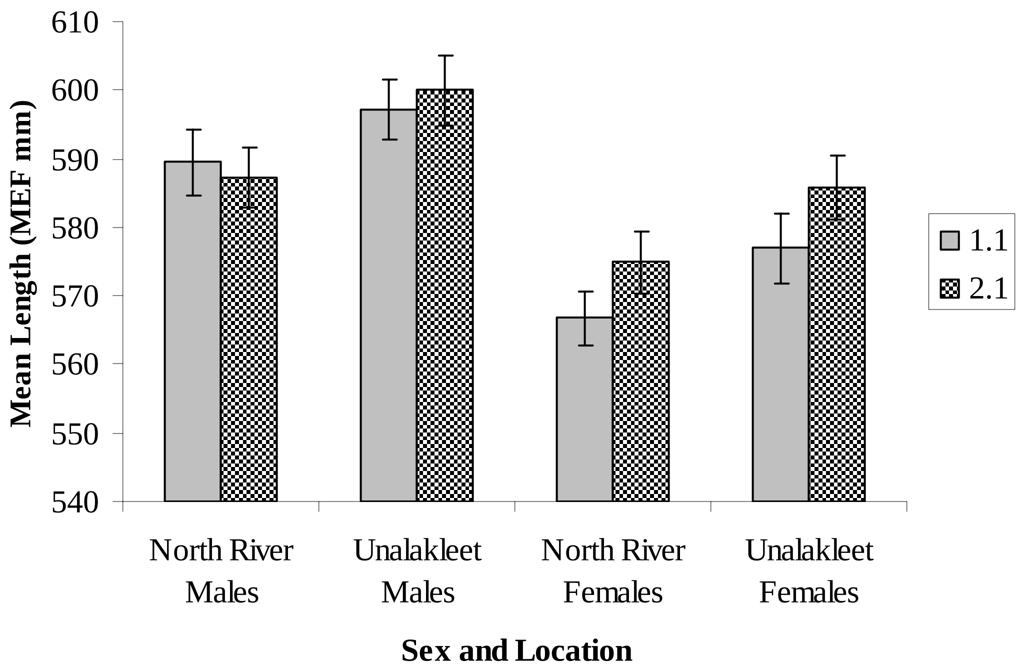

Figure 12.–Mean length of male and female coho in the North and Unalakleet rivers that were age-1.1 and -2.1, 2005. Error bars represent 95% confidence intervals.

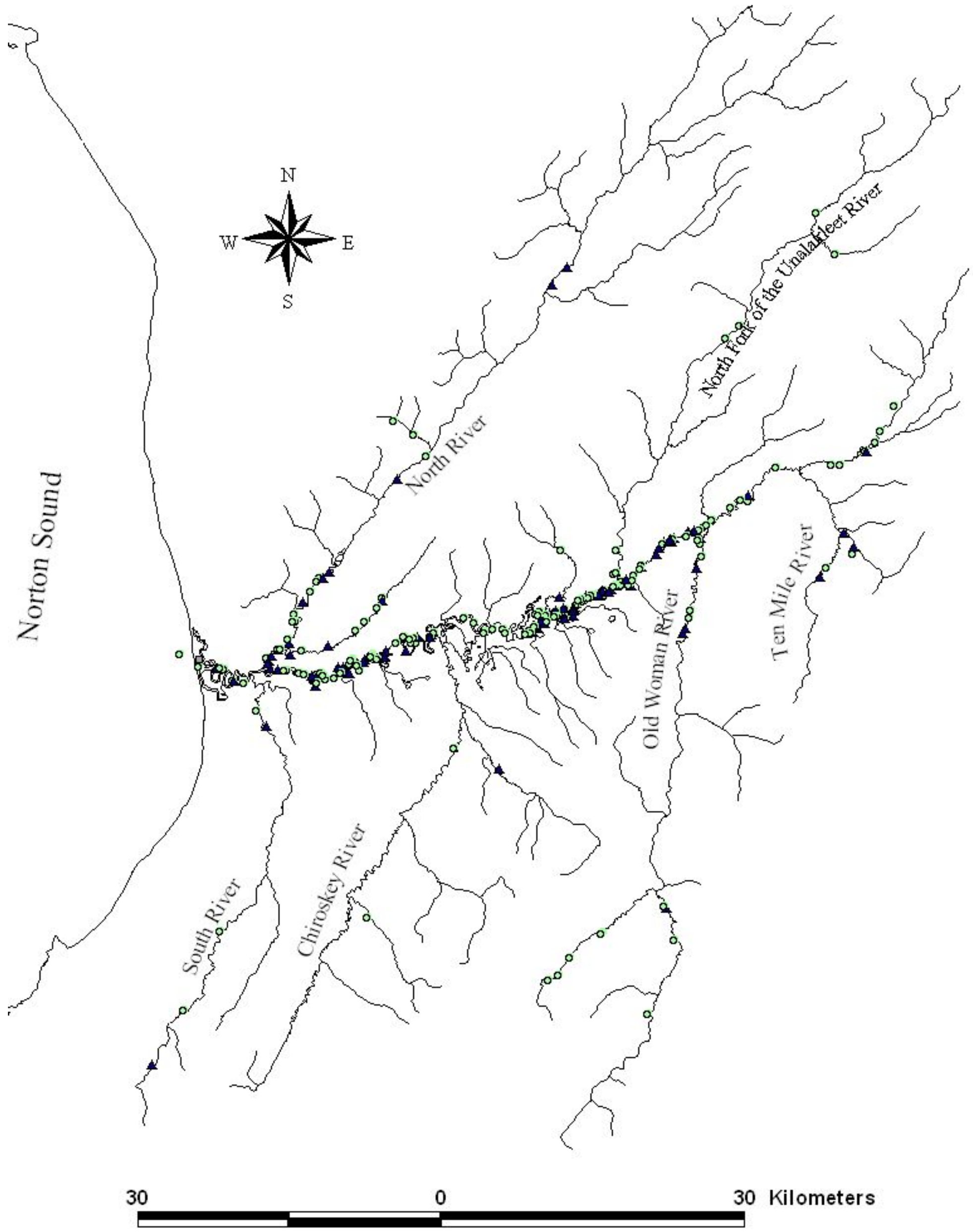

Figure 13.–The spawning locations of radio-tagged coho age 1.1 (circles) and 2.1 (triangles) in the Unalakleet River drainage in 2005.

NORTH RIVER AND UNALAKLEET RIVER COMPARISONS

The primary goal of this study was to determine whether the number of coho salmon counted at the North River counting tower provides a reliable index of coho salmon escapement in the entire Unalakleet River drainage. To evaluate the efficacy of the North River Tower assessment as an index of the entire population, this project examined the proportion of the total run enumerated at the tower and the run timing and the age, length, and sex composition of fish migrating past the tower compared to other areas of the drainage.

The proportion of coho salmon entering the Unalakleet River that migrated past the North River tower was 14% in 2004 and 15% in 2005 (Joy et al. 2005), which indicates the North River supports a moderate, but consistent fraction of the run. Coho salmon sampled in the North River had a smaller mean length than those sampled in the Unalakleet River and had a significantly smaller length distribution (Figure 10). This is unlikely to have resulted from biased sampling as the same beach seine was used for sampling in both rivers, and sampling occurred in both rivers on each sampling day. While North River coho salmon were smaller than their counterparts in the Unalakleet River, their run-timing (Figure 8) and age distribution (Figures 11 and 12) patterns were similar to coho salmon in the Unalakleet River. The run timing of North River coho salmon appeared to overlap the run timing of both upper Unalakleet/tributary coho and mainstem coho (Figure 9). Thus, the results of the first two years of this study suggest the North River tower may provide a reasonable index the of Unalakleet River coho salmon population.

ABUNDANCE

In 2005, as in 2004, the objective criteria for precision of abundance estimates given in the project objectives were not met. This occurred despite an increase in the sample size from 200 radio tags in 2004 to 300 radio tags in 2005. This is the result of two conditions. The first is that sample sizes in 2004 were estimated based on a much smaller in-river abundance than that which occurred in 2005. The 2005 coho run was, by all indications, the largest on record. Secondly, the run was earlier than the historic run timing and thus tagging strategies were shifted on August 27 when the coho run began to taper off. This created a data set that necessitated temporal stratification around this day which further reduced the precision of the estimate.

AGE COMPOSITION

While the relative abundance of age-1.1 and -2.1 coho salmon spawning in the North and Unalakleet rivers in 2004 appeared to vary temporally and geographically (Joy et al. 2005), there was no apparent variation in the abundance of age-1.1 and -2.1 coho salmon in 2005. The proportion of age 1.1 and 2.1 coho did not differ between the early and late portions of the run (Figure 11) nor was there an apparent difference in the spawning location of age 1.1 and 2.1 coho (Figure 13). The mixture of coho age-1.1 and -2.1 is not unusual for coho stocks and the ratios observed in this study are comparable to other studied coho runs at this latitude (Sandercock 1991). The age ratio within a stock may vary between years (Sandercock 1991) as was seen between 2004 (Joy at al. 2005) and 2005.

ACKNOWLEDGEMENTS

Thanks go to our partners in this project: Henry Ouyumick of the Unalakleet IRA and Mike Scott of the U.S. Bureau of Land Management. Thanks also go to the residents of Unalakleet for their support of this project. The Commercial Fisheries Division in the Nome ADF&G office including Gary Todd, Jeff Estensen, Wes Jones, and Brad Fuerst provided invaluable assistance. Matt Evenson provided editorial suggestions and Sara Case performed final formatting of this report. Thanks are given to Jim Tweedo and Hageland Aviation for providing piloting services during aerial surveys. Additional thanks goes to the Unalakleet IRA field technicians Jacob Ivanoff, Dean Towarak, Zayne Panuptchuk, and Jack Koutchak as well as to ADF&G field technicians Nissa Bates, Virgil Davis and Tristan Davis. Special thanks go to Tim Sundlov from BLM. Partial funding for this project was provided by BLM and the U.S. Fish and Wildlife Service, Office of Subsistence Management, provided $89,665 in funding for this project in 2005 through the Fisheries Resource Monitoring Program, under agreement number 701811J333.

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APPENDIX A

Appendix A1.–Detection of size or sex selective sampling during a 2-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R), using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test, comparing M and C, is conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling. Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first of second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C as described above, using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. When the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared between samples using a two sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:		
Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:		
Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:		
Reject H_o	Reject H_o	Reject H_o

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

-continued-

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, an overall composition parameters (p_k) is estimating by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{, and} \tag{1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right) \tag{2}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i;

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

Appendix A2.–Tests of consistency for the Petersen estimator. (from Seber 1982, page 438).

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing[a]

Area/Time Where Marked	Area/Time Where Recaptured				Not Recaptured
	1	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[b]

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked $(n_2\text{-}m_2)$				

III.-Test for equal probability of capture during the second event[c]

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured $(n_1\text{-}m_2)$				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i\theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j\theta_{ij}p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

APPENDIX B

Appendix B1.–Data files used to estimate parameters of the coho salmon abundance and length, age and sex distributions in the Unalakleet River drainage, 2004.

Data File	Description
04UnakPopEst.xls[a]	Excel spreadsheet with finalized population parameters and estimates.
Chapman Estimates – Unk Coho 2004.xls[a]	Excel spreadsheet with finalized Chapman calculations and estimates for coho abundance.
Tagged Coho Log – Final.xls [a]	Excel spreadsheet with consolidated data on all radio-tagged coho including calculations used in Chapman estimates.
Unk Coho Master Data – Final.xls[a]	Excel spreadsheet with raw data on all captured and sampled coho in the Unalakleet River drainage in 2004 including data from upriver sampling occasions.

[a] Data files have been archived at the Alaska Department of Fish and Game, Research and Technical Services, Anchorage, Alaska 99518; and are available from the authors, Division of Sport Fish, 1300 College Road, Fairbanks, AK 99701.